

A Dissertation Submitted  
in Partial Fulfillment of the Requirements for  
the Degree of Doctor of Philosophy  
in the University of Michigan

CONTRIBUTIONS OF INSTRUCTIONAL FILMS TO THE  
TEACHING OF HIGH SCHOOL SCIENCE \*

I

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THE investigation<sup>1</sup> described in this article represents an effort to determine the extent to which certain selected instructional films in science contribute, particularly by means of the unique and the specialized functions of the medium, to the realization of three of the major objectives of science education in the secondary schools. These three teaching objectives, in terms of which the film contents were analyzed, are:

- I. To effect an understanding of scientific principles that will function in the everyday life and activities of the student.
- II. To teach the elements of scientific method as skills to be employed in the solution of problems.
- III. To develop the scientific attitudes.

EVALUATIVE CRITERIA

In preparation for the projected analysis of contents of some of the best available motion pictures dealing with aspects of science, a comprehensive list of both the unique and the specialized functions of the

motion picture in science was drawn up, based on the published works of several specialists in visual aids and on the investigator's personal experiences in using science films.

*The Unique Functions*

For the purposes of this study a "unique function" is defined as any educational experience which the motion picture medium can provide but which cannot be provided by any other type of audio-visual aid.

*1. Methods or Processes Not Directly Demonstrable*

It will be considered that a unique function is served if a scene aids in depicting *Methods or Processes Not Directly Demonstrable* which are of such a nature that a special form of pictorial demonstration is necessary in order to instruct the audience in the method by which men perform the processes involved. These processes must involve human manipulations and activities which for complete demonstration under ordinary circumstances would

- a. Extend over too long a period of time for classroom purposes.

\* An abstract of an unpublished doctoral dissertation at the University of Michigan, 1945, entitled *Contributions of Instructional Films to the Teaching of High School Science*.





*Examples:* Methods of breeding hybrid corn.  
Methods of preparing spotted-fever vaccine.

b. Involve a complexity of intermediate steps or coördinated acts making special treatment through the motion picture medium necessary in order to show the interrelationship of the various parts to the whole process.

*Examples:* Mass production methods in the meat-packing industry.  
Method of recovering and preserving an archeological or paleontological specimen.  
Methods of mining coal.

c. Be impossible because of the student's confinement in time and space.

*Examples:* Methods of fighting a forest fire.  
Method of tapping a rubber tree in the Amazon forest.

## 2. Action Observable Only Vicariously

It will be considered that a unique function is served if a scene depicts *Action Observable Only Vicariously*, thereby providing such experiences as contribute to the student's awareness or understanding of the scientific subject matter under consideration, but which would be unavailable, vicariously or otherwise, except through the motion picture medium because of

a. The student's confinement in time and space.

*Examples:* Behavior of beavers in the wild state.  
Origin of icebergs at the end of sea-borne glacier.

b. The limitations of the ordinary high school's demonstration facilities.

*Examples:* Natural phenomena shown by demonstrations involving high-vacuum equipment.  
Responses of living visceral organs to various stimuli.

## 3. Observable Action Simplified Through Animation

It will be considered that a unique function is served if a scene depicts *Observable Action Simplified Through Animation* so as to eliminate intervening or irrelevant

details where several interrelated processes or mechanisms are operating at the same time.

*Examples:* Operation of individual parts of a gasoline engine.  
The path of a single organism, such as a gnat, moving rapidly among others of its kind.

## 4. Unobservable Action Through Animation

It will be considered that a unique function is served if a progressive series of drawings is used to depict *Unobservable Action Through Animation*. (A moving arrow or pointer will not be considered to be an example of animation.)

*Examples:* Sound wave phenomena.  
Heart action, showing the timing of the valves and flow of blood.

## 5. Slow-Motion Photography

It will be considered that a unique function is served if a scene depicts, through *Slow-Motion Photography*, action which is

a. Unobservable because of the extreme rapidity of the subject's motion.

*Examples:* Movements of the wing feathers of a bird in horizontal forward flight.  
Effect of the impact of a racket upon the shape of a tennis ball.

b. Readily observable but moving too swiftly to permit the observer to gain a clear understanding of the nature of the motion.

*Examples:* Muscular and skeletal action of a racing greyhound.  
The dive of a kingfisher into water.

## 6. Time-Lapse Photography

It will be considered that a unique function is served if a scene depicts, through *Time-Lapse Photography*, action which is

a. Unobservable because of the slowness and/or remoteness of the moving object.

*Examples:* Diffusion of a gas throughout another gas.  
Movement of Jupiter's satellites during an eight-hour period.

b. Readily observable but moving too



slowly to permit the observer to gain a clear understanding of the nature of the motion.

*Examples:* Movements accompanying the opening of a flower.  
Movements among changing cloud shapes.

### 7. *Simulation of Reality Through the Incorporation of Recorded Sound*

It will be considered that a unique function is served if a *Simulation of Reality* is achieved through the incorporation of recorded sound or sound-effects with the film's visual record of the motion in a natural phenomenon, but only when the sound assists in reifying the aspect of science which is the theme of the film.

(Such sound effects as the barking of a dog in a film devoted to the life habits of a snapping turtle, or the whistle of a harbor craft while the use of a sextant is being demonstrated will not be considered as satisfying this criterion of a unique function.)

*Examples:* Roar and rumble of an active volcano.  
Songs and cries of birds.  
Note of a tuning fork.

### *The Specialized Functions*

For the purpose of this investigation a "specialized function" of the motion picture medium is defined as any educational experience which may be provided by other visual aids as well as by motion pictures, but to which the motion picture is capable of contributing uniquely because of the technical versatility of the medium.

#### 1. *Photomicrography*

It will be considered that a specialized function is served, if, through *Photomicrography*, a scene depicts action otherwise unobservable except through use of individual microscopes or microprojection.

*Examples:* Brownian movements.  
Activities of microorganisms.

#### 2. *Miniature Photography*

It will be considered that a specialized function is served if, through *Miniature*

*Photography*, a scene depicts action otherwise unobservable except through use of moving scale models or other miniature devices.

*Examples:* Course of erosion of a mountain range into a peneplain. (Simulating reality by photographing changes in a miniature landscape.)  
Action of lightning striking a power line. (Simulating reality by photographing an electrical discharge on a miniature landscape with scale-models of buildings, trees, and cattle.)

### 3. *The Human Elements of Science Through the Dramatic Medium of the Motion Picture*

It will be considered that a specialized function is served if, through the *Dramatic Medium of the Motion Picture*, the Human Elements of Science are depicted.

(The scene must demonstrate how a scientist attacks and solves his problems. It should show him actually pondering the problem, experimenting, studying results, and drawing conclusions. His use of the scientific method and his possession of the scientific attitudes should be revealed by *pictorial* means, and the depiction should be accompanied, in the narration or titles, by direct verbal reference to method or attitudes.)

*Examples:* Use of the scientific method.  
Scientific attitudes of scientists at work.  
Scientific attitudes and habits of mind among laymen.

Expressed thus in the form of criteria by which the contents of films might be analyzed, this list of functions was submitted to four specialists in the teaching of science, who judged each criterion with regard to its appropriateness, practicability of application, objectivity, and comprehensiveness.

Criteria were also prepared for the purpose of indicating as concisely as possible the conditions under which the contents of the films might be considered to be



making a contribution to one of the three major objectives of science teaching. It was decided to credit only those scenes with contributing to one of the three objectives, during the presentation of which a *direct reference* was made in the narration or titles to a principle, an attitude, or an element of scientific method. This was done in order to render the findings more objective, and to eliminate any tendency on the part of the investigator to read into the scenes implications not necessarily justified or subtle ideas which were not likely to be sensed by students viewing the films' contents, and which might not have been in the minds of the men who planned and produced the films.

#### *Contributions of Films to Objectives of Science Teaching*

1. It will be considered that an expressed idea in a film makes a contribution to the understanding of a SCIENTIFIC PRINCIPLE if it seems reasonable to infer (that is, if there is defensible evidence to indicate) that the narrator of a sound film or the author of sub-titles in a silent film had a definite scientific principle in mind and was manifestly attempting to teach it. This principle must have photographic or narrated data to illustrate it and must satisfy at least one of the following conditions:

a. The expressed idea must be unmistakably a statement of a scientific principle, satisfying the criteria of a principle, or the narrator must designate it to be a principle. In the latter case, also, it must satisfy the criteria of a principle.

*Example:* In reflection of light, the angle of incidence is always equal to the angle of reflection.

b. The statement must be capable of being reworded so as to become a scientific principle, without loss of its essential idea.

*Examples:* But all matter, including gas molecules, attracts other matter.

Restated, this becomes:

All bodies of matter attract other

bodies of matter with a force which varies directly as the product of their masses and inversely as the square of the distance between them.

c. The statement must employ a technical term or phrase which has direct reference to an accepted scientific principle, or which cannot be understood without an understanding of a scientific principle.

*Example:* Both the submarine and the dirigible are designed to function through application of Archimedes' Principle.

The accepted scientific principle referred to here is:

A body immersed or floating in a fluid is buoyed up by a force equal to the weight of the fluid displaced.

*To be considered a scientific principle, a statement*

- (a) Must be a generalization.
- (b) Must be a clear statement of a process or an interaction.
- (c) Must be capable of illustration so as to gain conviction.
- (d) Must not be a definition.
- (e) Must not deal with a specific substance or variety, or with a limited group of substances or species.

2. It will be considered that a contribution to an understanding of An ELEMENT OF SCIENTIFIC METHOD is indicated in a film:

a. If the narrator's script, the actors' dialogue, or the sub-title script includes a direct reference to an Element of Scientific Method.

*Example:* We must now select the most likely explanation for this reaction and proceed to test that hypothesis experimentally.

b. If the narrator's script, the actor's dialogue, or the sub-title script employs a technical term or phrase which has direct reference to some aspect of the Scientific Method, or which cannot be understood without an understanding of the Elements of Scientific Method.



*Example:* Observing the flow of urine out of these tubes, we see that the rate of urine formation in the experimental animal on the right is much greater than in the control animal.

In this case the terms "experimental animal" and "control animal" allude to integral concepts in the scientific method.

c. If it seems reasonable to infer (that is, if there is defensible evidence to indicate) that the narrator, actor, or title author had an Element of Scientific Method in mind and was manifestly attempting to convey or demonstrate its meaning.

*Example:* Roux (Pasteur's assistant)—Have we found anything?

*Pasteur* (Peering through microscope) — Nothing definite. (Sighs) Try Again.

*Technician* (slumping wearily in his chair) Again?

*Pasteur*—Yes, again, *again*, and *AGAIN!* Remember our aim: Find the microbe; kill the microbe!

The Element of Scientific Method exemplified here is "Testing the hypothesis by carrying out the experiment with great care and accuracy."

(For a master list of the elements of scientific method, see the author's articles upon the subject appearing in earlier issues of this magazine.)<sup>2</sup>

3. It will be considered that a contribution to the understanding of a SCIENTIFIC ATTITUDE is indicated in a film:

a. If the narrator's script, the actors' dialogue, or sub-title script includes a direct reference which unmistakably indicates or refers to a Scientific Attitude.

*Example:* One of the marks of a true scientist is his insatiable curiosity to know more about the world around him.

This statement paraphrases the scientific attitude indicated in:

"A curiosity to know about one's environment."

b. If the narrator's script, actor's dialogue, or the sub-title script calls attention directly to the possession, or the lack, of a specific Scientific Attitude on the part of a character portrayed in the film, or of

any other person whose name or personality is involved in the film.

*Example:* Colonel Mackey (to his staff officers in Uganda)—If anyone can, Doctor Bruce will soon get to the bottom of things. He'll not rest until he's learned every fact any of you know about the Sleeping Sickness; and you'd better not palm off any of your fancy theories on him either. He'll check up on every blasted thing you say, and if you've been pulling his leg, he'll be back to throw the lie in your teeth. In a nice way, of course.

Two scientific attitudes are evidenced in these remarks:

"An unwillingness to accept as facts any statements not supported by convincing proof."

"The intention to respect another's point of view."

c. If it seems reasonable to infer (that is, if there is defensible evidence to indicate) that the narrator, actor, or sub-title author had one of the Scientific Attitudes in mind and was manifestly attempting to convey or demonstrate its meaning.

*Example:* We should be scientific about this, you know.

After all, I've had my fill of superstitions from these natives hereabouts. There's an explanation for what has been happening, if we can only discover what it is. In this case, the scientific attitude illustrated is:

"The belief that nothing can happen without a cause and that occurrences that seem strange and mysterious can always be explained by natural causes."

(For the master list of scientific attitudes used in this study, see Caldwell and Curtis' latest textbook for general science.)<sup>3</sup>

The foregoing criteria were also validated by the expert judgment of three specialists in the field of the teaching of science to determine whether each criterion was appropriate, practicable for application, objective, and comprehensive.

Attention should be called at this point to the fact that the three categories of functions (unique, specialized, contributions



to objectives) are not mutually exclusive. By way of illustration, one might consider the hypothetical case of a photomicrograph (specialized function) depicting organisms in slow motion (unique function), projected in conjunction with a reference by the narrator to some scientific principle (contribution to a major science objective). On the other hand, one scene might serve two or more unique functions at once, as in the case of a vibrating cello string depicted in slow motion with accompanying sound recording of the musical note thus produced. In the film analyses, scenes were found in several instances to serve at least two functions.

#### SELECTION OF FILMS FOR ANALYSIS

Although any random selection of science films might have been analyzed for evaluative purposes and the results found to be informative, it was believed that analysis of the *best* films available would be much more revealing of the degree to which classroom films have been developed in their effectiveness for realizing the three teaching objectives mentioned earlier, and for performing the unique and specialized functions of motion pictures. Therefore, two current catalogs<sup>4</sup> of teaching films, *Selected Educational Motion Pictures* (American Council on Education) and *The Film Utilization Guide* (University of Michigan) were examined. Those films which were rated "excellent" in each under the headings of astronomy, biology, chemistry, general science, geology, health and hygiene, physics, and physiology were noted. Thirty-eight such titles were found in the first catalog, twenty-eight of which were also listed in the second catalog. However, four of the latter had been rated as "good" rather than excellent, and as a consequence were excluded from the final selection.

#### TECHNIQUES OF ANALYSIS

A special form of check-sheet was next devised, upon which each individual scene of an entire film could be indicated as (1)

serving certain specified unique or specialized functions of motion pictures (if any), (2) contributing to one or more of the three objectives of science teaching (if any), or (3) serving no such functions or contributing to no such objectives. A trial analysis of one film which was not included in the list selected for study, was then made by the investigator for the purpose of devising and refining a routine of film analysis, gaining facility in its use, and testing the adaptability of the check-sheet for its purpose.

The following routine method of procedure was thus developed in practice and followed consistently throughout the twenty-four film analyses:

1. Prepare a blank check-sheet for use, filling in the film title, date, evaluator's name, etc.
2. Project the entire film once or twice at full projection speed to familiarize oneself with its contents.
3. If no printed transcript of narration is supplied with the film:
  - a. Number several sheets of paper in double-column from 1 to 100 or more to provide sufficient scene-numbers
  - b. Operate projector at slowest speed *without* sound
  - c. Identify each scene with a descriptive word or phrase, and enter these after the proper scene number
  - d. Re-project the film, checking for accidental omissions
4. If a printed transcript of narration is supplied with the film:
  - a. Operate projector at slow speed, but *with* sound
  - b. Enter the number of each scene upon the margin of the transcript opposite the corresponding point in the narration
  - c. Re-project the film, checking for accidental omissions
5. Study the film content to identify and tabulate the scenes which serve unique or specialized functions, as described in the criteria set up for the purpose:
  - a. Project the film at medium speed *with* sound
  - b. Record the function served by the scene (if any) in rough form by abbreviations opposite each scene listed on the transcript or numbered page
  - c. Re-project the film, checking for errors or omissions in the record
  - d. Transpose the corrected record from



its rough form on the scene lists to the check-sheet.

6. Examine the narration and titles to discover, and to copy *verbatim*, the statements in which a scientific principle, an element of scientific method, or a scientific attitude is indicated as described in the criteria set up for that purpose:
  - a. Review the entire narration carefully to detect omissions and oversights in the record of analysis
  - b. Transpose to the check-sheet the corrected record of the film's contributions to the three teaching objectives
7. Complete the check-sheet record by tallying those scenes which did not serve a unique or a specialized function nor contribute to a major objective.

The reliability of the investigator's judgment in the application of the criteria was checked by means of a second analysis of three different films (14.8 per cent of the total number of scenes) approximately six or seven weeks after the initial analysis. The two analyses were found to be in agreement on the marking of the various

scenes in 90.2 per cent of the cases. The validity of the investigator's judgment was also checked by having most of the same three films (12.7 per cent of the total number of scenes) analyzed by three experienced science teachers, who worked as a committee and employed the same techniques of analysis as those used by the investigator. The percentage of agreement between the combined judgments of the committee and those of the investigator was 86.0 per cent. A comparison of the investigator's second (check) analysis, performed from six to seven weeks after the originals, with those of the judges showed a percentage of agreement of 95.5 per cent. These measures were deemed to indicate that the reliability and validity of the investigator's judgment in applying the criteria to the films' contents were sufficiently high to warrant the use of the data gained in the course of this investigation. (Part II will appear in the April issue.)

## CONTRIBUTIONS OF INSTRUCTIONAL FILMS TO THE TEACHING OF HIGH SCHOOL SCIENCE \*

### II

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PART I of this article described in detail an investigation to determine the extent to which certain selected instructional films in science contribute, particularly by means of the unique and the specialized functions of the motion picture medium, to the realization of three of the major objectives of science education in the secondary schools. The twenty-four films selected for study

\* Part I appeared in the March, 1946, issue of SCIENCE EDUCATION.

were assumed to represent the best available in the field of science, since each had been listed as "excellent" in two outstanding film catalogs, a rating determined in both cases on the basis of several hundred panel and/or classroom appraisals of the films.

The 1734 scenes which made up the twenty-four films were analyzed critically in the light of carefully prepared evaluative criteria and the data thus derived were



appraised in an effort to achieve a valid measure of the excellence of the selected films as teaching tools in the science classrooms of our high schools.

#### FINDINGS AND CONCLUSIONS

1. *The chief functions now performed by the best motion pictures available for teaching science are (a) the provision of vicarious experiences by "bringing the world into the classroom" (i.e., action observable only vicariously), and (b) the*

TABLE I

SUMMARY OF DATA COLLECTED BY FILM ANALYSIS

| Film Number | Total Number of Scenes in Film | Number of Unique Functions Served | Number of Specialized Functions Served | Number of Contributions to Objectives | Number of Scenes with No Function or Contribution |
|-------------|--------------------------------|-----------------------------------|----------------------------------------|---------------------------------------|---------------------------------------------------|
| *1          | 28                             | 26                                | 0                                      | 1                                     | 2                                                 |
| 2           | 49                             | 16                                | 3                                      | 1                                     | 31                                                |
| 3           | 61                             | 21                                | 13                                     | 4                                     | 27                                                |
| 4           | 86                             | 35                                | 1                                      | 3                                     | 47                                                |
| 5           | 43                             | 23                                | 1                                      | 5                                     | 18                                                |
| 6           | 55                             | 57                                | 5                                      | 0                                     | 3                                                 |
| 7           | 102                            | 83                                | 0                                      | 1                                     | 18                                                |
| 8           | 52                             | 23                                | 8                                      | 10                                    | 21                                                |
| 9           | 52                             | 26                                | 1                                      | 13                                    | 24                                                |
| 10          | 115                            | 88                                | 0                                      | 0                                     | 27                                                |
| 11          | 70                             | 41                                | 2                                      | 5                                     | 26                                                |
| 12          | 28                             | 23                                | 4                                      | 4                                     | 5                                                 |
| 13          | 81                             | 72                                | 0                                      | 5                                     | 8                                                 |
| 14          | 87                             | 2                                 | 8                                      | 0                                     | 77                                                |
| 15          | 52                             | 25                                | 6                                      | 5                                     | 19                                                |
| 16          | 51                             | 29                                | 2                                      | 6                                     | 18                                                |
| 17          | 100                            | 82                                | 1                                      | 0                                     | 17                                                |
| 18          | 35                             | 42                                | 0                                      | 8                                     | 6                                                 |
| 19          | 110                            | 0                                 | 14                                     | 0                                     | 96                                                |
| 20          | 110                            | 14                                | 9                                      | 0                                     | 87                                                |
| 21          | 120                            | 7                                 | 53                                     | 0                                     | 62                                                |
| 22          | 91                             | 26                                | 15                                     | 0                                     | 50                                                |
| 23          | 90                             | 29                                | 0                                      | 10                                    | 60                                                |
| 24          | 66                             | 49                                | 0                                      | 12                                    | 15                                                |
| Totals      | 1734                           | 839                               | 146                                    | 93                                    | 764                                               |
| Medians     | 68                             | 29                                | 2                                      | 3.5                                   | 22.5                                              |
| Averages    | 72.3                           | 35                                | 6.1                                    | 4.0                                   | 31.8                                              |
| Ranges      | 28                             | 0                                 | 0                                      | 0                                     | 2                                                 |
|             | to 120                         | to 88                             | to 53                                  | to 13                                 | to 96                                             |

\* Table I is read thus: The first film, containing a total of 28 scenes, was found to serve unique functions in 26 instances, specialized functions in no instances, and to contribute to 1 major science objective. Two scenes served no function and made no contribution, as functions and contributions are described by the evaluative criteria.

*depiction of unobservable action through animation.*

The data gathered in this study indicate that scenes falling in the two categories mentioned above amounted to 56.9 per cent and 23.1 per cent respectively of the total number of scenes serving unique functions, and constituted 27.6 per cent and 11.2 per cent respectively of all the scenes in the twenty-four films analyzed. The unique function ranking third in frequency of occurrence was *time-lapse photography*, representing only 9.7 per cent of the scenes serving unique functions and 4.7 per cent of the total number of scenes in the films.

2. *Several of the unique and potentially valuable functions of motion pictures are utilized far too little in films designed to teach science.*

Conspicuous among these are (a) scenes simplified by animation, (b) slow-motion photography, (c) sound recorded to reify the subject studied, and (d) instruction in a process or method of doing something. In the investigation here reported, scenes serving these functions comprised 0.0 per cent, 0.1 per cent, 2.2 per cent, and 2.7 per cent respectively of the total number of scenes in the films (see Table II).

3. *Photomicrographs of objects in motion are used extensively.*

Although only fifty-two such photomicrographs were found (3.0 per cent of the total number of scenes), one or more occurred in over half (i.e., fourteen) of the twenty-four films. The frequencies of occurrence of photomicrographs in the fourteen films ranged from one to twelve per film, with a median frequency of three.

4. *Miniature photography, which is exceedingly valuable as a means of depicting certain types of subject matter in science, is not utilized to the extent which seems justified.*

In spite of the fact that the scientific concepts dealt with in some of the films were of such a nature that miniature photography could have been utilized to advan-



tage, this specialized function was served by none of the 1734 scenes analyzed.

### 5. The depiction of the human elements

TABLE II

PERCENTAGE OF THE TOTAL NUMBER OF SCENES (1734) FOUND TO SERVE UNIQUE FUNCTIONS, SPECIALIZED FUNCTIONS, TO MAKE CONTRIBUTIONS TO MAJOR SCIENCE OBJECTIVES, AND TO SERVE NO FUNCTION AND MAKE NO CONTRIBUTION

| Function or Contribution                                                                             | Number of Scenes | Percentage of Total |
|------------------------------------------------------------------------------------------------------|------------------|---------------------|
| <i>Unique Functions:</i>                                                                             | 839              | 48.4                |
| Methods and Processes not Directly Demonstrable*..                                                   | 46               | 2.7                 |
| Action Observable Only                                                                               |                  |                     |
| Vicariously.....                                                                                     | 477              | 27.6                |
| Simplified Observable Action                                                                         | 0                | 0.0                 |
| Animation.....                                                                                       | 194              | 11.2                |
| Slow Motion Photography                                                                              | 2                | .1                  |
| Time Lapse Photography..                                                                             | 81               | 4.7                 |
| Recorded Sound with Action                                                                           | 39               | 2.2                 |
| <i>Specialized Functions:</i>                                                                        | 146              | 8.4                 |
| Photomicrography.....                                                                                | 52               | 3.0                 |
| Miniature Photography.....                                                                           | 0                | 0.0                 |
| Human Elements of Science                                                                            | 94               | 5.4                 |
| <i>Contributions to Objectives:</i>                                                                  | 93               | 5.4                 |
| Scientific Principles .....                                                                          | 85               | 4.9                 |
| Elements of Scientific Method .....                                                                  | 8                | .5                  |
| Scientific Attitudes .....                                                                           | 0                | 0.0                 |
| <i>No Unique Function or Specialized Function, and No Contribution to a Major Science Objective:</i> | 764              | 44.1                |

\* Table II is read thus: The total number of instances in which scenes were found to serve unique functions was 839. This represents 48.4 per cent of the total number (1734) of scenes to be found in the twenty-four films analyzed.

of science (i.e., of the personalities, attitudes, and methods of scientists at work) is limited largely to those films of the inspirational-dramatic type,\* and hence are

\* Two distinct types or groupings could be observed in the selection of science films studied. The first of these might well be called the *informational-expository* type. It was devoted exclusively to the presentation of scientific subject matter, and was usually highly organized for that purpose only.

The second group might be named the *inspirational-dramatic* type. With one exception these films invariably dramatized the STRUGGLES of some scientist, usually in the field of medicine, to combat a dread disease or to overcome the mental inertia of a society which refuses to see

not being demonstrated as intelligently or as fully as their importance in science warrants.

Of the ninety-four scenes which served this specialized function, only one appeared in a film of the informational-expository type. Although the bearded scientist peering tensely at test tubes amidst a forest of miscellaneous glassware was often dramatized, these glimpses never seemed to serve any definite pedagogical end.

6. *There is good evidence that the best instructional films in science, as represented by the twenty-four selected films, may teach, or at least are fitted to teach, scientific principles.*

When the six films of the inspirational-dramatic type, in which the theme or subject-matter tended to preclude the possibility of developing understandings of scientific principles, were disregarded, it was found that sixteen of the remaining eighteen films went beyond the mere presentation of scientific information. In addition to furnishing mere facts, these films summed up the facts with generalizations which met the criteria for a scientific principle. These generalizations occurred in frequencies ranging from one to thirteen, averaging about five and one-third principles per film.

7. *The best available scientific films reveal no definite intention or attempt to teach scientific principles.*

No opportunity was provided in the films analyzed for the observers to generalize upon the facts presented. It seemed reasonable to infer that the prime objective of those who produced the instructional films studied was, quite simply, to *dispense information*. The narrator knew so much which had to be told. In the brief ten minutes which were at his disposal, he often had to discuss broad fields of subject matter quite

the Truth because of bigotry or superstitious ignorance. Nearly all were narrated in the ringing, society-shaming style of John Nesbitt's series of story-telling radio programs known as "The Passing Parade."



comprehensively, cramming large amounts of generalized information into a short space of time. Indeed the wordings of many of the generalizations stated by the narrators of films seemed to bear out the contention that the exemplification of a principle was *not* the film-maker's original intention, but rather that the principle had resulted quite accidentally, as an expedient in the interests of brevity.

No direct evidence was found in this study to indicate that the makers of films hold the elucidation of a scientific principle to be either a primary objective of science teaching or pedagogically valuable in itself.

8. *If the films here selected be representative of the best, then even the best motion pictures do not adequately provide for teaching the Elements of Scientific Method.*

No evidence was discovered which indicated that the producers of the films had been aware that the *method of inquiry* is a vital aspect of science. The motion pictures of the informational-expository type were invariably replete with scientific facts, but deficient in exposition of the method used to discover those facts. Only one producer (Dr. Anton J. Carlson of the University of Chicago) appeared to have recognized the desirability of teaching the Scientific Method in films in connection with scientific subject matter, and deliberately incorporated Elements of Scientific Method into his films. The inspirational-dramatic type of film naturally dealt almost exclusively with the "struggles" of scientists to solve problems, yet nowhere were their methods of problem-solving intelligently demonstrated.

9. *On the basis of the evidence found in this sampling, it must also be stated that no intention or effort to teach the Scientific Attitudes through the medium of the best instructional films available today is evident.*

The depiction of the human elements of science, which often involve both the scientific attitudes and scientific method, was

confined almost exclusively to the inspirational-dramatic type of motion picture. Vivid illustrations of scientists' reactions to the troubles and problems encountered as they pursued their researches were frequently depicted on the screen. By an observer well versed in the scientific attitudes, these illustrations could have been used to teach the scientific attitudes directly. Also, the scientific attitudes were often implied by the contrast between the non-scientific attitudes of the "crowd" and the scientific attitudes of the scientist, whom the crowd invariably opposed. This contrast provided material which was appropriate and suitable for teaching scientific attitudes, since the student automatically identified himself with the scientist and resented the injustice and intolerance demonstrated by the crowd; yet no direct reference to any scientific attitude was found in any of the films analyzed.

In no instance was an attitude definitely indicated as being scientific or unscientific. Hence the awareness of the scientific attitudes depicted dramatically upon the screen probably reached the viewer's consciousness only in the vague formlessness of emotional stimulation, rather than in the form of clearly verbalized ideas. Consequently, since such evidence as is available strongly indicates that attitudes cannot be effectively inculcated incidentally or indirectly, it seems unlikely that these films would function to an appreciable extent in inculcating scientific attitudes.

10. *There is evidence, therefore, which indicates that the film producers not only fail to provide the means of achieving the most important objectives of science teaching to the extent possible through the motion picture medium, but that they also fail to use optimally the unique and specialized functions of which the medium is capable.*

Unique functions are served by about one-half of the scenes (48.4 per cent), and specialized functions by about one-twelfth



of the scenes (8.4 per cent) of the films' contents (see Table II). Furthermore, a little over a twentieth (5.4 per cent) only were found to contribute to one of the three major objectives of science teaching. Therefore, nearly half (44.1 per cent) of the contents of the twenty-four films served no unique or specialized functions and contributed to none of the three major objectives.

The fact that at least a part of this approximate half is needed in all probability to effect *continuity* in the film does not mitigate the deserved criticism that many potent means of effecting important outcomes in science teaching were not employed in these films to the extent that was practicable.

#### RECOMMENDATIONS

At least three great cultural achievements may be credited to scientists and considered to be part of the heritage which teachers of science are obligated to pass on to rising generations: (1) a generalized body of knowledge of the material world, (2) a definite method of inquiry by which that knowledge was accumulated, and (3)

the habits and attitudes of mind which characterize the best scientists and greatly enhance their chances for success in their search for knowledge. In planning and producing future motion pictures in science, film-makers should make certain that their products are definitely designed to teach these three major components of science, and that optimal use is made of the unique and specialized functions of the motion picture medium for achieving these objectives.

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THE ELEMENTS OF SCIENTIFIC METHOD

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THE purpose of the investigation [1] reported in this article was to derive a comprehensive list of the elements of scientific method which would be suitable for instructional purposes in the secondary schools.

TECHNIQUES

At the outset of the study no adequately validated list of these elements existed, although much material relative to the scientific method had previously been published. A survey of this literature was therefore made in order to locate a wide variety of ideas regarding the nature of the scientific method. As a result forty-three books and magazine articles were revealed to contain analyses of the method in sufficient detail to warrant their inclusion in the list of contributing materials. Each element of scientific method found in these sources was recorded upon a card in the

exact words of the author or in a phrase conveying the same meaning. An outline was next constructed which included all the separate elements, or aspects, of scientific method found in the sources. This outline, bulky and repetitious, was then arbitrarily simplified through elimination of insignificant details and consolidation of many varied expressions of the same ideas into single statements. In this way a sequence of twelve major steps in the scientific method was evolved, organized in the order in which these might logically be expected to occur in the solution of any scientific problem of such a nature as to involve all twelve steps. The final list contained, besides the twelve main headings, forty-two sub-items.

This list was submitted in questionnaire form for validation by the expert opinion of twenty-two research scientists of the University of Michigan staff. The judges



were asked to check each item and sub-item on the questionnaire as either *Essential*, *Desirable* but unessential, or *Unnecessary* and not properly an element of scientific method.

As each of the questionnaires was returned, the values assigned by the judge to its various items were tabulated upon a chart. Considerable difficulty was at once encountered, however, since many of the judges had not consistently followed the directions in marking the items. Some had marked only the minor elements, leaving the major elements unvaluated. Others had assigned values after making qualifying statements or insertions which in some cases altered the original meanings of the items. Hence for the sake of establishing uniformity in the method of tabulating the judgments of the evaluators, the following rules of policy were arbitrarily set up:

1. If a major element is unevaluated but all the minor or sub-elements under it are given identical ratings, the major element shall be considered as having the same rating as the highest given any sub-element.
2. If the wording of an item is changed either by rewording or qualification but its original idea is not altered, the item is to be tabulated as if its original wording were unchanged.
3. If the correction or qualification made changes the essential meaning of the item, the rating assigned to it by the judge shall not be tabulated, but the criticism of the item implied by the suggested change shall be taken into account in preparing the final list of the elements.
4. If a part of a questionnaire has been marked and the remainder is left blank, those ratings in the portion which has been judged shall be tabulated.

When the number of ratings as *E*, *D*, or *U* had been totaled for each item in accordance with the foregoing rules, the percentage of evaluations falling into each category was computed by dividing the number of ratings in each case by the total number of evaluations submitted for that item and multiplying the resulting fraction by 100, or

$$\text{Percentage} = \frac{\text{Number of ratings in category} \times 100}{\text{Total number of ratings submitted by judges}}$$

For example, a total of 22 judgments were reported upon Item I of the questionnaire, i.e., "Being sensitive to a problematic situation, and having a desire to solve it." Of these, 18 were *E*, 2 were *D*, and 2 were *U*. Thus 18/22 or 81.8 per cent of the judges considered Item I to be *essential* in the scientific method, 2/22 or 9.1 percent considered it *desirable* but not essential, and a like number and percentage rated it *unnecessary*.

Next, in order to secure a basis for determining the relative importance of the elements of scientific method listed in the questionnaire, the following formula was arbitrarily devised and applied to the data:

$$\text{Numerical Value} = \frac{2E + D - 2U}{2},$$

in which *E* represents the percentage of judges who rated the item as *Essential*, *D* the percentage of judges who rated it as *Desirable*, and *U* the percentage of judges who rated it *Unnecessary* in the scientific method. The relative value for Item I may be obtained by substituting the percentages stated in the example above thus:

$$\begin{aligned} \text{Numerical Value of Item I} &= \frac{(2 \times 81.8) + 9.1 - (2 \times 9.1)}{2} \\ &= \frac{154.5}{2} \\ &= 77.3 \end{aligned}$$

Item I has, therefore, a relative value of +77.3 in a scale ranging from -100 to +100 (the two extreme scores which would result from unanimous disapproval or rejection of the item by the judges and from unanimous disapproval or acceptance of the item by the judges respectively.)

#### FINDINGS

The relative values of the fifty-four major and minor elements, as computed by means of the formulas described above, were found to range from +100 in the cases of two of the major elements, to +18.5 for one of the minor elements, with a median value of +85.7. The two elements which the judges unanimously rated as *essential* were:

- VII Carrying out the experiment with great care and accuracy.
- X Drawing a conclusion or arriving at a solution to the problem based on an honest, unbiased appraisal of the data.



The element rated lowest (being held as *essential* by three, *desirable* by eleven, and *unnecessary* by five judges) was:

XII-a Attempting to generalize in a tentative way from the specific experimental data.

The median relative value for the fifty-four elements was only about fifteen points below the highest point in a 200-point scale. Furthermore about three-fourths (78 per cent) of the elements were given values within thirty points of the highest possible rating, i.e., above the 170th point on the 200-point scale. These results seemed to indicate that the judges were preponderantly favorable toward the general conception of the scientific method as presented in the questionnaire.

In view of these facts it seemed justifiable (1) to retain as a master list the entire fifty-four elements of scientific method as presented in the original questionnaire, and (2) to prepare an abbreviated and simplified list of the elements based upon the more important or highly evaluated items of the master list, wherewith to fulfill the purpose for which the foregoing research was undertaken. To this end twelve minor elements the relative values of which were below seventy were arbitrarily deleted from the revised list. The forty-two items remaining were condensed in wording and reorganized to form a final list consisting of ten major and seventeen minor elements of scientific method. These major and minor elements were thoroughly checked for ambiguity of expression and errors of omission by three specialists in the teaching of science. The list thus produced, technical in nature and expressed in a vocabulary best suited for use at the college or university level, was as follows:

#### ABBREVIATED LIST OF THE ELEMENTS OF SCIENTIFIC METHOD

- I *Sensing a problem and deciding to try to find the answer to it.*
- II *Defining the problem.*  
Stating the problem in words.

Analyzing the problem into its essential factors.

- III *Studying the situation for all facts and clues bearing upon the problem.*

Drawing upon past experiences, both personal and those reported in literature, for possible explanations or generalizations to account for the phenomena observed.

- IV *Making the best tentative explanations or hypotheses as to the possible solution of the problem.*

Recognizing the assumptions which must be made if one goes beyond the known facts in formulating a hypothesis.

- V *Selecting the most likely hypothesis.*

- VI *Inventing and carefully planning one or more experiments to test the hypothesis, isolating the experimental factor wherever possible by using a control.*

Deciding upon the kinds of evidence which should be collected.

Choosing reliable methods of collecting the evidence.

Refining measuring instruments to the degree warranted by the nature of the problem.

Practicing to gain skill in manipulation in order to secure accurate results.

- VII *Testing the hypothesis by carrying out the experiment with great care and accuracy.*

Preventing as far as possible all uncontrolled variations in the conditions which might affect the results.

Making quantitative measurements of experimental results and estimating the probable error of such measurements.

Recording the results, adhering strictly to standard definitions and usage of scientific terms.

Organizing the pertinent data so that they may be studied and summarized.

- VIII *Running check experiments involving the same experimental factor to verify the results secured in the original experiment.*

Studying the conditions of the experiment in order to detect any omissions, defects, or errors, particularly those errors which might have been introduced in the experimental results by coincidence or chance.

Recognizing and, if possible, checking further the validity of the assumptions involved in setting up the experiment.

- IX *Drawing a conclusion.*

Arriving at a solution to the problem based on an honest, unbiased appraisal of the data.

Suspending judgment when results are not conclusive.

Calling attention in the conclusion to those basic assumptions which it has

been necessary to maintain throughout the procedure.

- X *Making inferences based on this conclusion when facing new situations in which the same factors are operating.*

This more technical list was then reworded item by item in simplified language so as to make it readily comprehensible to students in the seventh or eighth grade. The results of forty-five investigations of vocabulary difficulty in textbooks by Curtis [2] seem to indicate that the non-technical vocabularies should be confined largely to the words which occur in the first six thousand-word levels of Thorndike's list,[3] and that all technical and non-technical words introduced which occur in thousand-word levels above the sixth in Thorndike's list should be defined in context. In keeping with these recommendations, the abbreviated list was rewritten and the simplified version was submitted to three experts in the teaching of science and further revised until in their unanimous opinion it was suitable for use by the pupils of the junior high school.

The ultimate list for which the foregoing investigational steps were undertaken follows:

#### THE ELEMENTS OF SCIENTIFIC METHOD FOR HIGH-SCHOOL STUDENTS

The Scientific Method is a good way to solve many kinds of problems of everyday life.

The Scientific Method always begins with a problem. The problem may be any question for which you do not know the answer. For example, it might be one of these:

"What makes my hand so sticky after helping to decorate our Christmas tree?"

"Should I wear one heavy coat, or two or three light ones when I play outdoors in cold weather?"

"What makes that hammering noise in my father's automobile engine?"

"Is it better to fall sideways or backward when sliding for second base in a ball game?"

"What causes people to have colds?"

How such a problem might be found is illustrated in the following paragraph:

Suppose that a frying pan with some grease in it has been heating upon the kitchen stove. You notice that whenever a raw egg or a slice of raw potato is dropped into it, the grease pops and

spatters. If any of the hot fat falls upon your hand, it burns painfully. You might say to yourself, "What makes hot fat spatter that way?" This is a problem. If you should then decide to try to find out why it does, you would have taken the first step in the Scientific method.

The first step in using the Scientific Method is to:

- I. *Notice something that makes you think of a question that you would like to be able to answer, and make up your mind to try to find the answer to it.*

Let us see how the other steps of the Scientific Method might be used in solving your problem:

- II. *Decide exactly what the question or problem is, and state it clearly in words.*

In this case it would be: "What makes hot fat spatter when a slice of raw potato is frying in it?"

- III. *Study all the facts and see how they relate to the problem.*

In studying the problem, use everything you know, not only what you have learned from your own experiences, but also what you have learned from other people and from books.

For example, you may believe from what you already know, that the popping is really a small explosion, and that, therefore, the heating may have something to do with what happens.

Then you notice that whatever causes the spattering seems to be *in the potato itself*, because the fat does not spatter much, even when very hot, until the food touches it.

- IV. *Make as many possible answers to the problem as you can think of.*

Scientists call this step, "Making hypotheses."

The following possible answers might occur to you in this case:

(1) The *heating* of the fat makes it spatter.

(2) Something *on the potato*, possibly water, makes the grease spatter.

(3) Something *in the grease* makes it spatter.

- V. *Select from these possible answers or hypotheses the one you think is most likely to be the right one.*

The first answer does not seem probable because you have seen pans of fat heated until smoking hot without spattering. For the same reason, the third answer does not seem probable. Therefore, if any of the three is the right answer, it seems most likely to be the second one.

- VI. *Make up and carefully plan an experiment to find out whether the answer you selected is the right one.*

In this case you would plan an experiment to find out whether the water on the potato causes the spattering.

Plan to do an experiment in two parts whenever possible.

In this case one part would be to fry a slice of potato that has water on it, and the other



part would be to fry another slice like the first one except that you wipe all the water off it before you fry it.

These two parts of the experiment are exactly alike in every way except one, and that is called the *experimental factor*.

The only difference between your two experiments is, that one slice has water on it and the other has not. *Water here is the experimental factor*, because it is the one factor that is different in the two parts of the experiment.

The part of the experiment that does not have the experimental factor in it is called the *control experiment*.

As a control, you will fry some slices of potato in hot fat *without any water on them*. This can be done if the slices are carefully dried with a towel before being dropped into the grease.

The part of the experiment which includes the experimental factor may be called the *true experiment*.

As the true experiment, you will fry some slices of potato in hot fat *with plenty of water on them*. This can be done if the slices are taken directly from a bowl of water and dropped into the grease.

Remember that the experimental factor must be the *only* difference between the true and the control experiments. Then any *differences* in the results of the two experiments will be due to the experimental factor.

VII. *Carry out the experiment with great care according to the plan.*

Make as careful observations as you can. Whenever your answer must be exact, make careful measurements of the results if you can.

When the two experiments are carried out, you find that the dry slices only sizzle, while the wet slices cause the grease to pop and spatter.

VIII. *Repeat the experiment to see whether you get the same results the second time. This second experiment is called a CHECK EXPERIMENT.*

Sometimes, instead of repeating the same experiment, an entirely new experiment using the same experimental factor is carried out as a check on the results.

Since water appears to be the cause of the spattering, you might take a few drops on your fingertips and let them drip into the hot grease, to see whether *water alone* behaves in the same way.

IX. *Draw your conclusion.*

Your conclusion should be stated so that it indicates whatever your experiments show, and *only* what they show.

For example, your conclusion might be: "It is the *water* on the sliced potato that makes the hot fat spatter from the pan."

X. *Use the facts you have thus learned when you face a new problem that is similar or related to this one.*

As a result of this experiment, you might decide to dry the slices of raw potato upon a towel hereafter, before dropping them into the pan, in order to avoid so much spattering of the grease.

Perhaps you might carry your investigations further by trying to find out whether it is the water in other foods, such as raw eggs or meats, which causes various cooking fats to spatter.

It is by using this method over and over again that our knowledge of the world about us increases; and the more we know about the world around us, the better we are able to live in it and to control it.

## CONCLUSIONS

In so far as the problem, techniques, and findings of this investigation may be acceptable, the following conclusion seems justified:

*The elements of scientific method are definite, distinct from scientific attitudes, and known and used by scientists.*

There is a high degree of agreement among the research scientists of the University of Michigan as to what the elements of scientific method are. None of the fifty-four elements submitted tentatively for validation in the questionnaire was rejected by the majority of the twenty-two judges. The opinion has often been expressed by scientific workers that there is no such thing as "the scientific method"; yet for the twenty-two research scientists who judged the list of items critically in this study, the term does have a specialized meaning which can be expressed in terms of general policies and steps of procedure in the solving of a problem. This high level of agreement encourages the belief that the scientific method has been developed beyond the stage of subjective interpretation and is now becoming recognized as a definite, tried, and tested procedure in problem-solving. It seems justifiable to assume, therefore, that as soon as effective methods and means of teaching the elements of scientific method and the scientific attitudes are found, the high-school student's chances of success in meeting and solving everyday problems will be greatly



enhanced, and, as a consequence, the functional importance of science for general education will increase inestimably.

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